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An antenna

The present invention relates to an antenna and more particularly the invention relates to a multiple beam antenna. More particularly, but not exclusively, the invention relates to a low-profile multiple beam antenna with hemispherical coverage.

Background

Lens-based multiple beam antennas offer a viable alternative to phased array antennas and enable a range of affordable systems to be designed for future military platforms (aircraft, pod mounted, unmanned air vehicle (UAV), missiles, ships). Examples of such affordable systems include covert communications, battlefield target identification (BTID), and extra high frequency (EHF) and satellite communications. They are therefore relevant to many communication systems, electronic warfare (EW) electronic counter measurements (ECM) and possible radar applications.

Multiple beam antennas with electronically switched beams typically possess a wide field of view. Such multiple beam antennas employ a combination of full lenses and virtual source lenses, each one populated by a number of feed elements.

Designers of systems frequently request low-cost, high-gain antennas with a wide field of view. Phased array antennas are expensive with difficult engineering issues such as component layout and thermal management. Multiple beam antennas, employing spherical microwave lenses for beam forming, offer a more affordable solution to existing antenna requirements.

Microwave antennas that utilise spherical dielectric lenses are well known in the art. One example is known as a "Luneburg lens" and employs a spherical microwave lens with a specific continuous dielectric profile. The Luneburg lens has found wide use as wide-angle scanning antenna because of its ideal focussing properties and its complete symmetry.

Several methods of fabricating Luneburg lenses, capable of operating at microwave frequencies, have been developed. The most common method uses

a hemispherical-shell construction yielding an approximate stepped or graded index profile. Other methods that have been considered include fabricating microwave lenses with a continuous dielectric profile.

A microwave lens antenna that utilises a lens comprising one-half of a dielectric sphere mounted on a ground plane is known as a hemispherical lens or virtual source lens. Hemispherical lenses or virtual source lenses rely upon reflection from the ground plane, which in effect, provides and acts as the second half of the dielectric sphere. This type of lens effectively is half the size of full Luneburg lenses and is well known and often referred to as a half Luneburg lens.

Prior Art

Several applications have been found that exploit the advantages of hemispherical lenses. In one example of a prior art system, a collinear array of half Luneburg lenses mounted on a common ground plane, is utilised to construct a low profile, low radar cross section, high-gain antenna. Each hemispherical lens is fed by a single feed mounted on a feed arm. Beam pointing is achieved by rotating the ground plane and moving all feeds simultaneously along their feed arms.

In one particular type of large array of full or half Luneburg lenses, it has been proposed to build a radiometer with exceptionally high gain. The antenna was designed to operate at low microwave frequencies, typically less than around 5 GHz. Although low radar cross section is not an issue at these frequencies, half Luneburg lenses may be preferred, because the ground plane offers a way of mechanically supporting the weight of the lenses. Each lens may be fed by a single feed or clusters of feeds that are mounted on feed arms and are mechanically steered.

An example of a Luneburg lens is described in United States Patent US 5421848 (Maier et al). US 5421848 describes a method for fabricating a lens having a variable refractive index. The refractive index is varied, for example, by varying a characteristic of a thread that is used to fabricate the Luneburg lens.

By varying a characteristic, such as the density, size or chemical composition of the thread the refractive index can be varied.

Another example of a Luneburg lens is described in United States Patent US 5825554 (Maier et al). US 5825554 describes a method for fabricating lenses of a variable refractive index.

United States Patent 5781163 (Ricardi et al) describes a low profile hemispherical lens antenna on a ground plane.

It is the object of the first invention, to present a multibeam antenna that covers a hemisphere by electronically switched pencil beams. The multibeam antenna can be operated in both transmit and receive mode.

Summary of the Invention

According to a first aspect of the invention there is provided an antenna comprising: a plurality of part spherical and/or spherical lenses arranged in an array and supported on a ground plane, there being a plurality of feed elements for supplying signals to, and receiving signals from, said lenses and control means to selectively switch the feed elements to send/receive signals.

Ideally each spherical, or part spherical lens, accommodates a number of feed elements and beam ports. Utilising the spherical symmetry of the lens, a relatively wide field of view is then covered by each lens, ideally, without blockage between the electronically switched feed elements.

Preferably beam ports are located on the surface of a lens or at a convenient distance away from the lens surface. A beam port can either transmit a beam into any desired direction (transmit mode) or receive a signal from any desired direction (receive mode) from within the solid angle of view of the antenna.

Ideally feed elements are located adjacent a sector of a lens. Preferably the sector is bounded by an arc that subtends less than 90°. In this arrangement blockage is avoided.

In a particularly preferred embodiment antennas in the array are supported on surfaces or ground planes, at differing heights with respect one to another.

Advantageously hemispherical antennas are used and the antennas are oriented so that their rotational axes of symmetry are angled in different directions one to another.

A switching network 87 is conveniently provided and is able to select a single beam port of any lens. The switching network 87 is ideally electronically controlled and serves to switch feed lines in a particular orientation. A microprocessor or other controller may be used to control how and when feed lines are switched. A switching network 87, conveniently in the form of a binary array, is employed as part of the antenna feed system.

Conveniently antennas are mounted on flat surfaces. By arranging hemispherical lenses or combinations of hemispherical and spherical lenses in this manner, the antenna extends only half as far above a surface as was previously the case compared with conventional antennas employing full spherical lenses or reflectors.

In a particularly preferred embodiment an entire antenna system can be mounted behind a frequency selective surface (FSS) that is transparent to frequencies used by the lens, but opaque to other frequencies. This offers a great advantage in terms of radar cross section. The reduced physical height of a half Luneburg lens allows a more compact installation on a vehicle which simplifies the design of a combined rodome/FSS. This simplification and the simplification at the junction of the FSS and airframe reduces the radar cross-section. If suitably dimensioned and arranged, the profile of such a frequency selective screen may also help reduce aerodynamic drag, for example when the antenna is mounted upon the fuselage of a craft, aircraft or vessel.

Using a plurality of lenses, each having a number of beam ports, it is possible to arrange the beam ports such that each beam port is free of blockage from other beam ports. Blockage occurs when rays entering the lens impinge a feed. This is similar to blockage due to waveguide feeds in Cassegrain type reflector configurations.

Using several electronically switched beams, rather than a single mechanically steered beam per lens; a high switching speed can be realised. By utilising high-speed microwave switches, such as PIN diode switches, the operating speed of the switching network 87 that switches a signal to an individual beam port on a particular lens or part of a lens, is greatly enhanced. A high switching speed is vital for a number of applications such as electronic support measures (ESM) systems.

For the avoidance of doubt, it is pointed out that the antenna itself, is not an array antenna, although a plurality of lenses and feed elements are employed. This is because the antenna is operated with a single beam switched on at any time. However, if multiple transmit/receivers are connected to the multiple feeds, a number of independent radiation pattern beams can be formed simultaneously. This allows the antenna to act as a node in a multi-point communication network.

According to a second aspect of the invention there is provided an antenna comprising: at least two part spherical and/or spherical lenses, a linear array of feed elements for supplying signals to, and receiving signals from the antennas, the lenses being supported at different orientations one to another and control means to selectively switch the feed elements to send/receive signals.

The invention is particularly useful in situations where scanning in one plane has to be very rapid, whereas scanning in a second plane, at much slower speed can be tolerated. An example of such a situation where this occurs is a communication system on an airborne platform. Banking manoeuvres might be quite rapid in one plane, whereas yaw manoeuvres are usually much slower in an orthogonal plane. This means that faster switching is required in the elevation rather than in the azimuth plane.

In a preferred embodiment the second aspect of the invention uses a lens-based multibeam antenna employing a hybrid scanning mechanism. Electronic switching between several beam ports is applied in one plane, whereas mechanical steering is applied in a second plane. Typically the second plane is orthogonal to the first plane.

In a particularly preferred embodiment the antenna is supported on a displaceable support which is arranged to move so that scanning can occur. Ideally a drive means is provided for displacing the support. The support may be a solid support having a circular base and an engagement mechanism, such as gear teeth, disposed about its periphery. One or more stepper motors are preferably provided and arranged to engage with the gears, in a rack and pinion type configuration.

A single spherical lens is therefore sufficient to achieve hemispherical coverage, offering a significant advantage in terms of cost and complexity of the multibeam antenna, compared with electronically switched beams.

Also, the number of beam ports is greatly reduced, leading to reduced cost and complexity of the switching network 87.

Preferred embodiments of the invention, will now be described, by way of exemplary examples only, and with references to the Figures in which:

Brief Description of the Figures

Figure 1 is a diagrammatical cross section of an example of a Luneburg lens, operated as a receiving multibeam antenna and shows regions of varying refractive index;

Figure 2 illustrates array geometry for a hemispherical (virtual source) Luneburg lens;

Figure 3 shows an overall view of a sphere and shows how an octant of a unit sphere may be populated by feed elements;

Figure 4a is an example of a Luneburg lens configuration, with four full Luneburg lenses, and feed elements for hemispherical coverage without blockage;

Figure 4b is a view of the lens configuration in Figure 4a, along line B-B;

Figure 5a shows a plan view of an example of a Luneburg lens antenna installation, based on a virtual source concept for full hemispherical coverage without blockage;

Figure 5b shows a cross sectional view through plane X-X, indicated in Figure 5a;

Figure 5c shows a cross sectional view through an alternative embodiment to the one shown in Figures 5a and 5b;

Figure 5d is a diagrammatical overall view of an alternative embodiment of a multibeam antenna;

Figure 6a is a plan view of a Luneburg lens antenna installation providing full hemispherical coverage, without blockage, comprising a full Luneburg lens and four hemispherical Luneburg lenses;

Figure 6b is a cross sectional view through plane P-P, indicated in Figure 6a;

Figure 7 shows a diagrammatical representation of a switching network for a binary tree of the type used to feed a Luneburg lens;

Figure 8 shows a diagrammatical view of an alternative embodiment of the invention showing a multibeam antenna assembly, employing a hybrid scanning mechanism; and

Figure 9 shows a diagrammatical view of an alternative embodiment of the invention showing a multibeam antenna assembly, behind a frequency selective surface.

Detailed description of Preferred Embodiments of the Invention

Preferred embodiments are now described with particular reference to Figures 4 to 8, However, so as to assist the reader some basic concepts, which are exploited by the invention, are briefly explained with reference to Figures 1 to 4.

Figure 1 illustrates the principle of operation of a Luneburg lens. Luneburg lens 10 is a spherically symmetric microwave lens. In Figure 1, the Luneburg lens comprises several shells, giving a stepped index profile. When a

beam of parallel rays 12 is incident upon the lens 10, rays 12 are focussed to a point 14 on a spherical surface 16, which is diametrically opposed from where the rays 12 are incident upon the lens 10. The spherical surface 16 is known as the focal surface of the lens.

By reciprocity, a Luneburg lens 10 can also be used as a transmitting device. Figure 1 illustrates this and shows a plurality of beam ports 18a to 18f. Each beam port 18 is connected to its respective feed element 20. By populating the focal surface 16 of the lens 10 with primary feed elements 20 and beam ports 18, beams 12 can be switched to point in different directions.

Luneburg lenses prove useful in a variety of antenna and scattering applications. In antenna applications, an advantage of Luneburg lenses is their ability to form multiple beams that may point in arbitrary directions. The ratio of the actual, physical diameter (D) of the lens, to the focal surface (radius f) of the lens (as shown in Figure 1), determines the dielectric profile of the lens 10. Generally, the relative permittivity (ε) assumes its maximum value at the centre (C) of the lens and decreases monotonically to one towards the surface of the lens 10.

For a classical Luneburg lens the focal surface (f) and the surface of the lens coincide (f/D=0.5). The permittivity then varies between 1 and 2. For larger values of f/D, the maximum permittivity is smaller than 2. In practical Luneburg lens implementations, the continuous dielectric profile is usually approximated by a stepped index profile, for example of the type shown in Figure 1.

Although a stepped dielectric is used to approximate the dielectric properties of a Luneburg lens, in the embodiment shown in Figure 1, it will be that other types of spherical lenses, such as "constant k" lenses or "two-shell" lenses, may be used to radiate signals from a focal point into a plane-wave beam or focus incoming beams to a point.

Figure 2 illustrates another concept that is relied upon by the invention. That is the virtual source concept. A hemispherical Luneburg lens 22 (HLL) is mounted on a conducting ground plane 24. Ray paths 12 are reflected at the surface of the ground plane 24, in accordance with Snell's law. Snell's law states that the angle of incidence (ϕ_I) is equal to the angle of reflection (ϕ_r).

Close inspection of Figure 2 shows a virtual incident plane wavefront 26 (indicated by dashed lines), emerging from below the ground plane 24, opposite antenna feed (not shown).

For classical planar arrays, or reflector antennas, the effective vertical dimension of the antenna aperture h_{eff} must be less than h, the maximum allowable protrusion of the antenna 22 above the ground plane. The same applies for antenna installations based on full Luneburg lenses. By comparison, the effective vertical dimension of a hemispherical Luneburg lens antenna aperture h_{eff} can be twice as large as the physical height h. The inherently larger aperture of a hemispherical Luneburg lens results in an antenna gain of twice that of a conventional antenna, with the same aperture height h protruding above the ground plane 24 . For airborne platforms this means that aerodynamic drag and radar cross section contribution can be reduced, compared with a conventional reflector or array antenna of the same effective size. If the antenna is enclosed by a frequency selective radome, radar cross section can be reduced for frequencies outside the operation band.

The first aspect of the invention uses electronically switched beams to achieve hemispherical coverage. This is achieved by controlling and manipulating beams, without individual beam ports blocking one other. Figure 3 illustrates a situation showing how this kind of blockage is avoided.

Referring to Figure 3, a feed element 30 is located, say, at the "North Pole" (0,0,1) of a Luneburg lens. Blockage is avoided provided that no feed element is located on the Southern Hemisphere, (assuming that the full Luneburg lens aperture is utilised). Similarly, if a second feed element 32 is located on the equator at (1,0,0), no blockage occurs provided that there is no feed element on the hemisphere described by $x < 0$. Finally, if a third feed element 34 is located on the equator at (0,1,0), no blockage occurs if there is no feed element on the hemisphere described by $y<0$. The boundaries imposed by the no-blockage condition for the three discussed points define an octant of a unit sphere depicted in Figure 3. If active feed elements are placed in this octant only, no blockage occurs.

Full hemispherical coverage can therefore be achieved by four full Luneburg lenses, each having one octant as shown in Figure 3, populated by feeds. Figure 4 shows the top view and two cross-sectional views of a Luneburg lens configuration for hemispherical coverage without blockage.

The embodiment shown in Figures 4a and 4b comprises four Luneburg lenses 10a, 10b, 10c and 10d whose centres are arranged in a square formation. Feed elements 20 are located inside this square area. Each Luneburg lens 10 contributes one quadrant of a full hemispherical view. The antenna installation 40 enables the full upper hemisphere to be covered by beams. Each of the four lenses 10a, 10b, 10c and 10d in turn covering western, northern, eastern and southern sectors.

Antenna installations on air, sea and land platforms are often required to be flush mounted to a mounting surface due to drag, Radar Cross Section (RCS) and aesthetics. If the antenna is attached to the surface of an aircraft, for example, the profile must be sufficiently small to prevent intolerable drag and air stream turbulence. In practice, the antenna is usually covered by a radome for environmental protection. A low-profile requirement forces medium and high gain antennas (>20dBi) to have an approximately rectangular or elliptical radiating aperture with a width to height ratio greater than four. The Luneburg lens configuration shown in Figure 4 is non-ideal in terms of radar cross section, as the height of the antenna installation, above a supporting structure (not shown), is at least the full diameter D of a Luneburg lens.

Figures 5a-b show, how the virtual source concept, as shown in Figure 2, is applied to construct an electronically scanned, multibeam antenna with hemispherical coverage, without blockage.

Figure 5a shows a plan view, whereas Figure 5b shows a cross-sectional view through the principal plane X-X. The antenna installation 40 comprises eight hemispherical Luneburg lenses 10a to10h respectively. The outer four hemispherical Luneburg lenses are mounted on a horizontal ground plane 46, whereas the inner four hemispherical Luneburg lenses are mounted on a ring-shaped section of ground plane that is inclined at an angle of 45° with respect to the horizontal plane. Each of the outer hemispherical Luneburg lenses 10 is

populated by feed elements 20, arranged on a rectangular sector measuring 90° in azimuth (as seen in Figure 5a) and 45° in elevation (as seen in Figure 5b). For the inner hemispherical Luneburg lenses 10e, 10f, 10g and 10h, feed elements 20 lie on a substantially triangular sector, (shown as T in Figure 5b), measuring 90° in azimuth and 45° in elevation.

Compared with the multibeam antenna installation 40 shown in Figure 4, the height of the installation h extending above the mounting surface, as indicated in Figure 5b, is reduced to half its value. This means that aerodynamic drag of installation 40 shown in Figures 5a and 5b are greatly improved compared with the installation shown in Figure 4.

Figures 5c and 5d show a yet further embodiment where additional lenses 10i, 10j, 10k and 10l are supported on a ring sectioned ground plane 34a outside the group of lenses 10a , 10b, 10c and 10d. An advantage of this is that the field of view is extended beyond hemispherical view.

Four triangular feed sectors 20 of the four inner hemispherical Luneburg lenses 10e, 10f, 10g and 10h, shown in Figure 5a, comprise a spherical cap 36 enclosing a half-angle of 45°. An alternative embodiment of this installation is achieved, without causing blockage, by using four hemispherical lenses 10r, 10s, 10t, and 10u and one spherical Luneburg lens 10w. Such an arrangement is depicted in Figure 6a and 6b. The installation 40, shown in Figures 6a and 6b, requires less Luneburg lenses than the one shown in Figure 5, as well as offering the same advantages in terms of low profile and a low radar cross section.

Figure 7 shows the topology of a typical switching network 87 comprising a plurality of switches 52 arranged in a binary tree. Top layer 54 of switches 52 is connected to feed elements 20. Each layer of switches 52 is fed by a layer below, having half as many switches 52. The input of the bottom layer is connected to a transmitter (not shown) or receiver (not shown), respectively. The number of switches 52 required for a binary switching network 87 feeding N beam ports 18 is:

$$1 + 2 + 4 + \ldots + N/2 = N - 1$$

The complexity of the switching network 87 is determined by the required gain of the multiple beam antennas. Because a high gain translates into a large number of beam ports 18, which itself translates into a large number of switches 52, the higher the gain, the greater is the requirement for switches. Each switch 52 requires a radio frequency (RF) path and a logic circuit (not shown). Radio frequency (RF) path and logic circuit supply bias voltages to select a particular beam, as is well known in the art.

If multi-throw switches (not shown) are used instead of double-throw switches, the corresponding tree is not a binary tree, and less switches and switching layers are required. It will be understood that the switching network 87 has to be accommodated somewhere between individual lens components.

Figure 8 shows schematically, an example of an assembly for use with the second aspect of the invention. There is shown a multibeam antenna 60 with a hybrid scanning mechanism 62. A single Luneburg lens 10 is required only therefore blockage is eliminated. A planar circuit board 64 contains feed elements 20. The feed elements 20 may comprise one of several types of antenna element to "feed" the lens (e.g. Vivaldi notches, bowties, etc.). These are arranged along a path following the lens profile (i.e. an arc) 66. As feed elements 20 are disposed in this manner blockage between beam ports 18 (see Figure 1) does not occur.

A switching network 87 is connected to the feed elements 20. Circuit board 64 provides rapid electronic scanning in elevation and is ideally mounted on a portion of a rotating cylinder 70. The axis of symmetry of Luneburg lens 10 is coincident with the axis of rotation of the rotating cylinder 70. A counterbalance 72 is supported on the cylinder 70 and balances the weight of the circuit board 64, switch network 68 and feed elements 20 . Input lines of the switching network 87, namely bias supply line 80, RF input/output lines 82, and control logic lines 84 are all connected through a rotary joint 74 in the axis of rotation. Azimuth steering is accomplished using two gears 90 and 92, driven by stepper motors 102 and 104. Ideally the gears 90 and 92 are located around an edge region 75 of the rotating cylinder 72. Ideally the control means

operates under supervision of a microprocessor 100 and is located in such as a computer.

It will be appreciated that other steering mechanisms, such as a single gear attached to the axis of rotation, could also be employed as possible solutions. However, the configuration shown in Figure 8 offers reliability and accuracy in terms of pointing and in terms of minimising the applied forces.

The complexity of the switching network 87 is greatly reduced compared with a full electronic scanning solution (not shown), since the scan is only in one plane, thus requiring considerably less beam ports 18. Switching is ideally supervised by a micro-processor and performed by a computer 100, such as a micro-computer. Computer 100 also controls the orientation of an antenna and actuation of any drive means, such as the stepper motor.

It will be appreciated that the invention herein described has a number of possible applications, for example on different types of platforms (ship, aircraft and land vehicle). A low profile, to reduce aerodynamic drag, is a crucial requirement for many of these systems and the invention offers this as well as other advantages over existing wide-angle scanning antennas.

It will be appreciated that variation may be made to the embodiments of the invention described herein without departing form the scope of the invention.

Claims

1. An antenna comprising: a plurality of part spherical and/or spherical lenses (10) arranged in an array and supported on a ground plane (24), there being a plurality of feed elements (20) for supplying signals to, and receiving signals from, said lenses (10) and control means (100) to selectively switch the feed elements (20) to send/receive signals.

2. An antenna comprising: at least two part spherical and/or spherical lenses (10), a linear array of feed elements (20) for supplying signals to, and receiving signals from the lenses (10), the lenses (10) being supported at different orientations one to another and control means (100) to selectively switch the feed elements (20) to send/receive signals.

3. An antenna according to claim 1 or 2 wherein the feed elements (20) are electronically switched to deliver signals to or receive signals from a beam port (18).

4. An antenna according to claim 3 wherein the feed elements (20) are arranged and means is provided to switch the feed elements (20), so as to avoid blockage.

5. An antenna according to any preceding claim whereby the, or each, feed element (20) is/are located on the focal surface (16) of a lens.

6. An antenna according to any of claims 3 to 5 wherein a beam port (18) can either transmit a signal in a desired direction (transmit mode) or receive a signal from a desired direction (receive mode) from within its solid angle of view.

7. An antenna according to any preceding claim wherein feed elements (20) associated with a lens (10) are located adjacent a sector of a lens.

8. An antenna according to claim 7 wherein the sector is bounded by an arc that subtends an angle less than 90°.

9. An antenna according to any preceding claim wherein antennas in the array are supported on surfaces or ground planes (46) and are oriented so that their rotational axes of symmetry are angled in different directions one to another.

10. An antenna according to any preceding claim wherein a switching network (87) is able to select a switch (52, 54) which directs a signal via a particular feed element (20) to a beam port (18) of any lens.

11. An antenna according to claim 10 wherein the switching network (87) is electronically controlled and means is provided for determining the orientation of beam ports (18) that are switched.

12. An antenna according to either claim 10 or 11 wherein the switching network (87) is in the form of a binary array and is employed as part of an antenna feed system.

13. An antenna according to claim 12 wherein the switching network (87) is controlled by way of a computer (100).

14. An antenna according to any preceding claim in which an antenna is mounted behind a frequency selective surface (99) that is transparent to frequencies used by the lens, but opaque to other frequencies.

15. An antenna according to claim 14 wherein the frequency selective surface (99) is dimensioned and arranged, so that its profile reduces aerodynamic drag.

16. An antenna according to claim 15 wherein the frequency selective surface (99) is dimensioned and arranged for use with antennas mounted upon the fuselage of a craft, aircraft or vessel.

17. An antenna according to any of claims 3 to 16 having a plurality of electronically PIN diode switches (52) for switching a signal to an individual beam port (18) on a particular lens or part of a lens (10).

18. An antenna according to any of claims 3 to 16 having a plurality of high-speed microwave switches (52) for switching a signal to an individual beam port (18) on a particular lens or part of a lens (10).

19. An antenna according to any preceding claim wherein an antenna array (60) has a hybrid scanning mechanism comprising: means (64, 80, 100) for electronically switching between several beam ports (18) in a first plane, and a drive (92,102) means for steering the beam in a second plane.

20. An antenna according to claim 19 wherein the second plane is orthogonal to the first plane.

21. An antenna according to claim 20 wherein the drive means comprises: a solid support (70) having a circular base and an engagement mechanism (90, 92) disposed about its periphery and one or more stepper motors (102, 104) provided to engage with the mechanism (90, 92).

22. A method of operating an antenna using multiple transmit/receivers connected to multiple feeds (20), so that a plurality of independent radiation pattern beams are formed simultaneously, thereby enabling the antenna to act as a node in a multi-point communication network.

23. An antenna substantially as herein described with reference to the Figures.

24. A method of operating an antenna substantially as herein described with reference to the Figures.

Abstract

The present invention relates to an antenna and more particularly to a low-profile multiple beam antenna with hemispherical coverage, for example for use with a lens based antenna array.

In one embodiment the antenna comprises an array of part spherical and/or spherical lenses (10) supported on a ground plane (24). Optionally a frequency selective surface (99), such as a radome, covers the array. The antenna has a plurality of feed elements (20) supplying signals to, and receiving signals from beam ports (18) supported on the lens (10). Switching of feed elements (20) is achieved electronically using a binary switching matrix (87).

Another embodiment of the antenna comprises an array of part spherical lenses (10) supported on an airborne platform. As banking manoeuvres are fast compared with yaw manoeuvres faster switching is achieved in the elevation rather than in the azimuth plane.

Advantages of the invention are that a lower profile is achieved and blockage of feed elements is avoided.

(Fig 8 accompanies the Abstract)

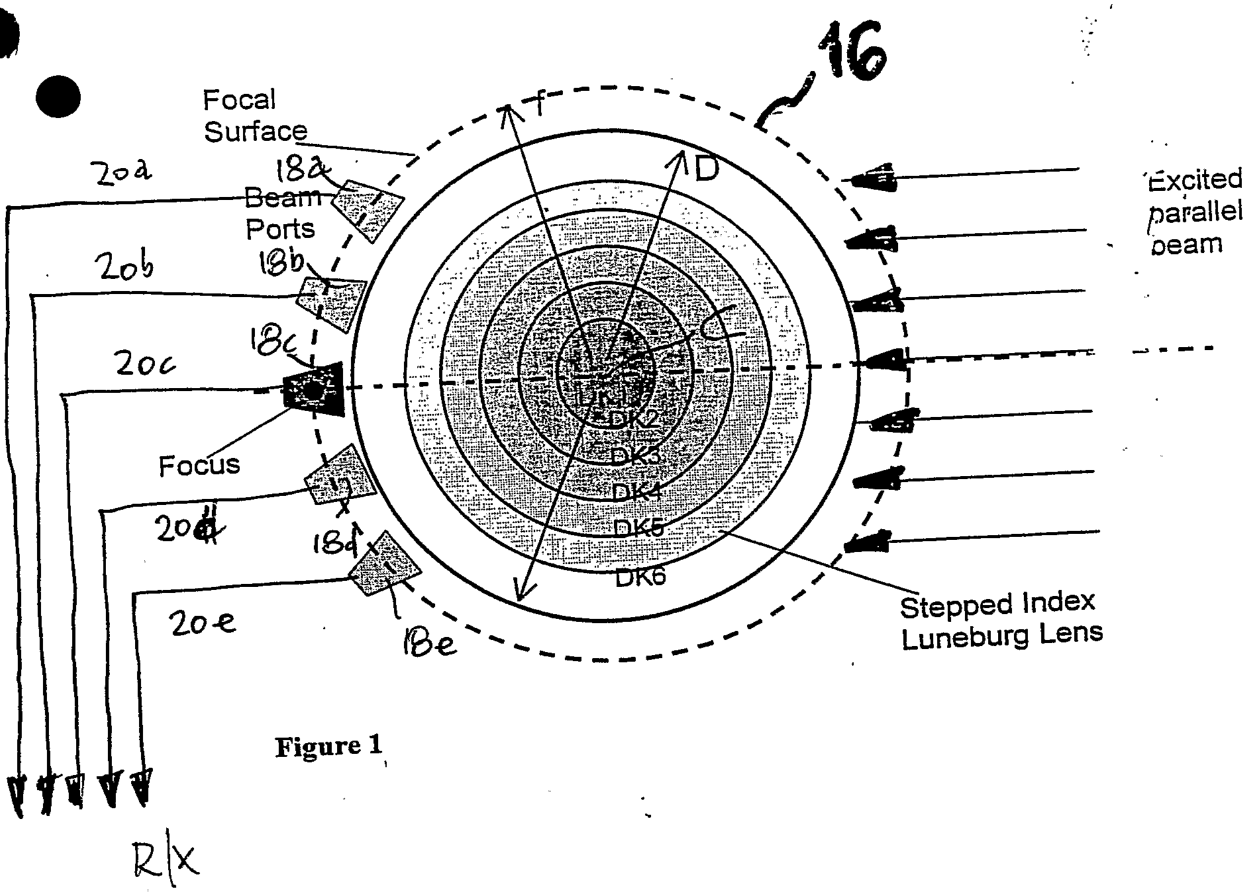

Figure 1

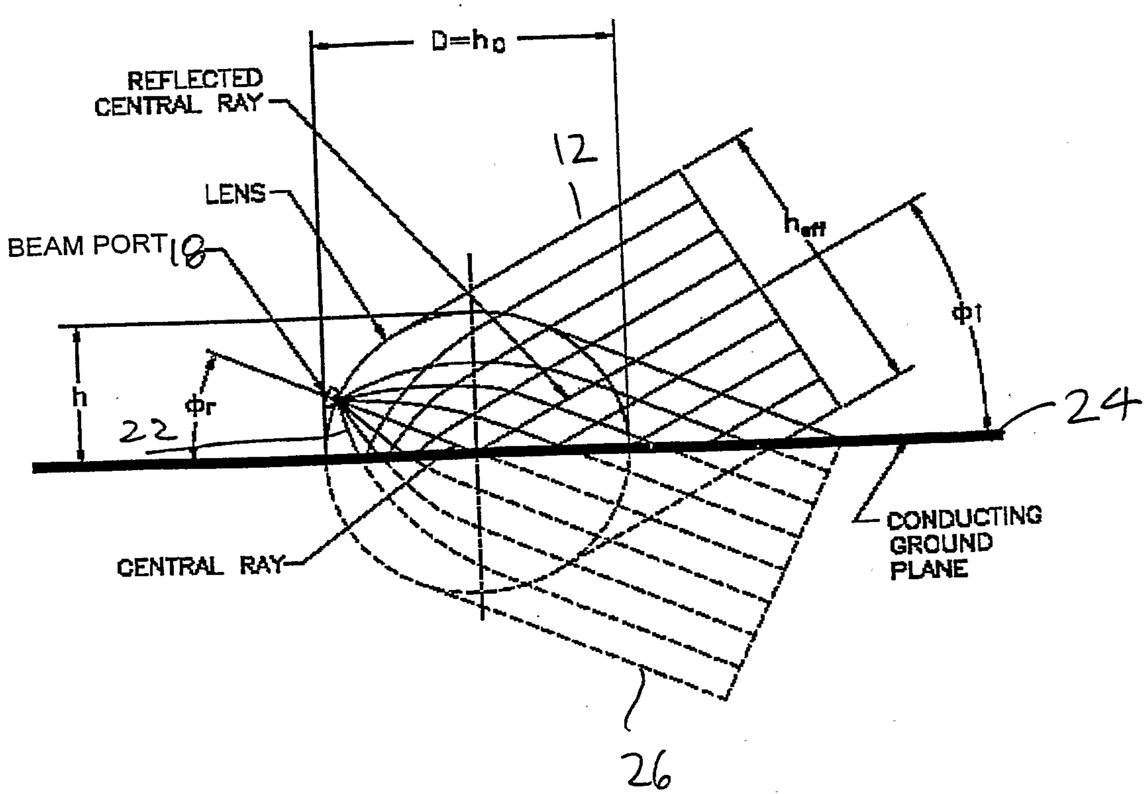

Figure 2

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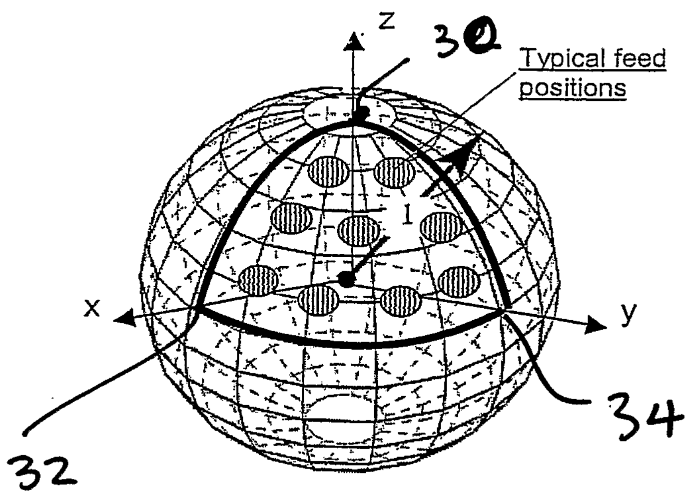

Figure 3

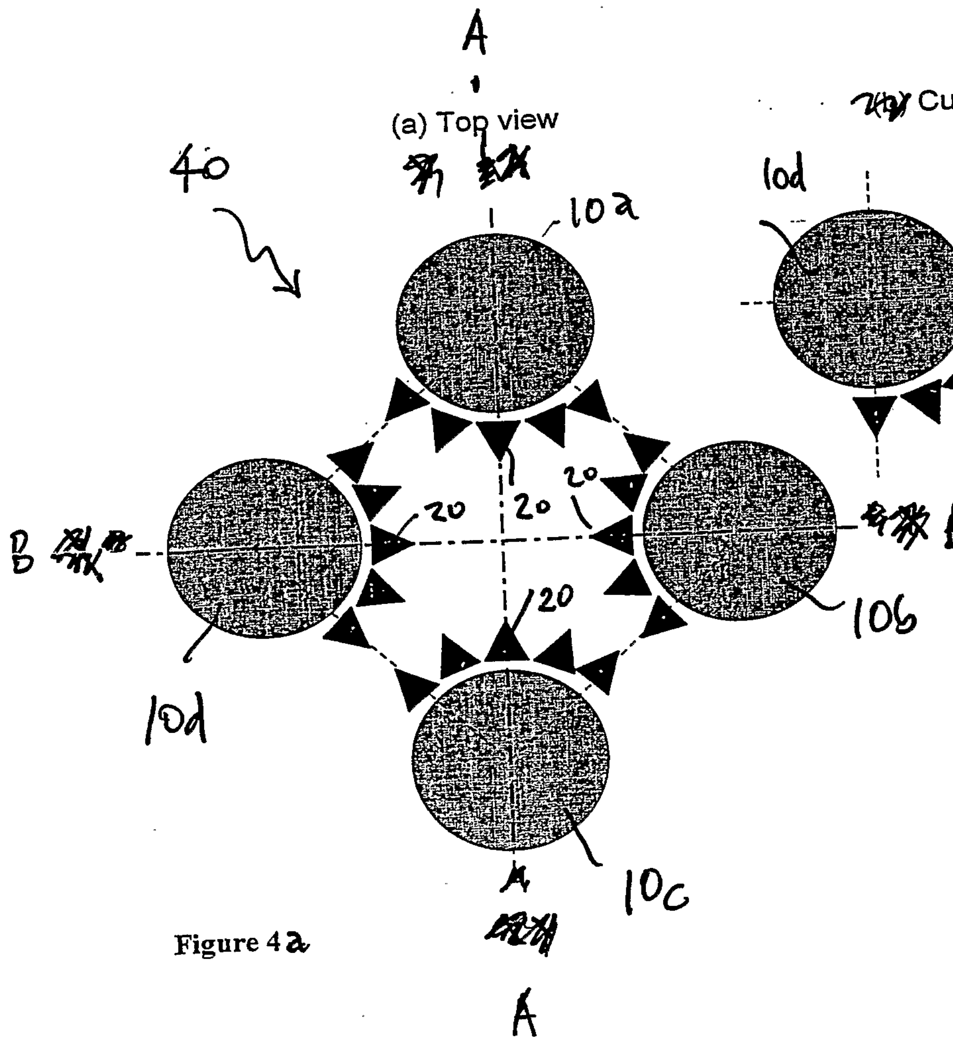

Figure 4a

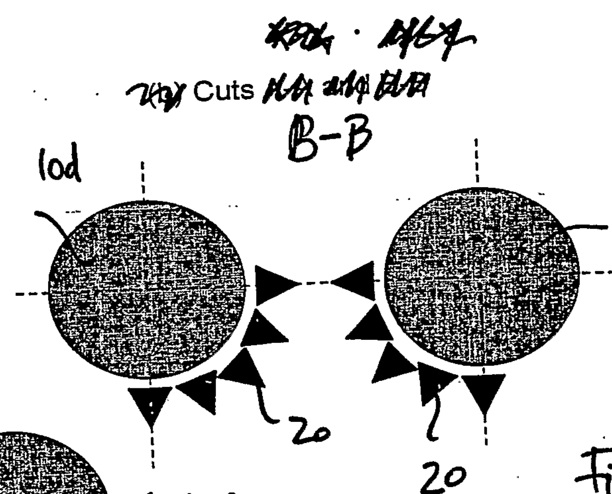

Figure 4b

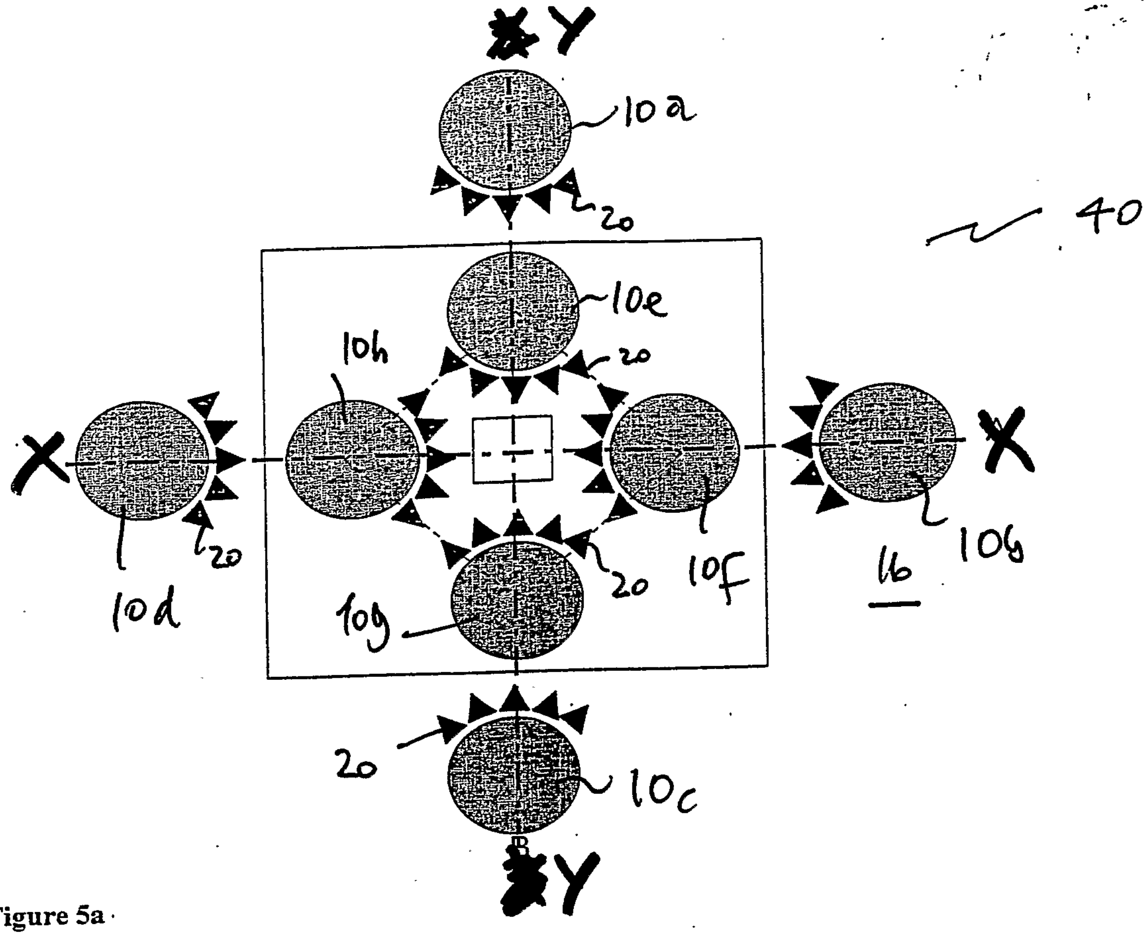

Figure 5a

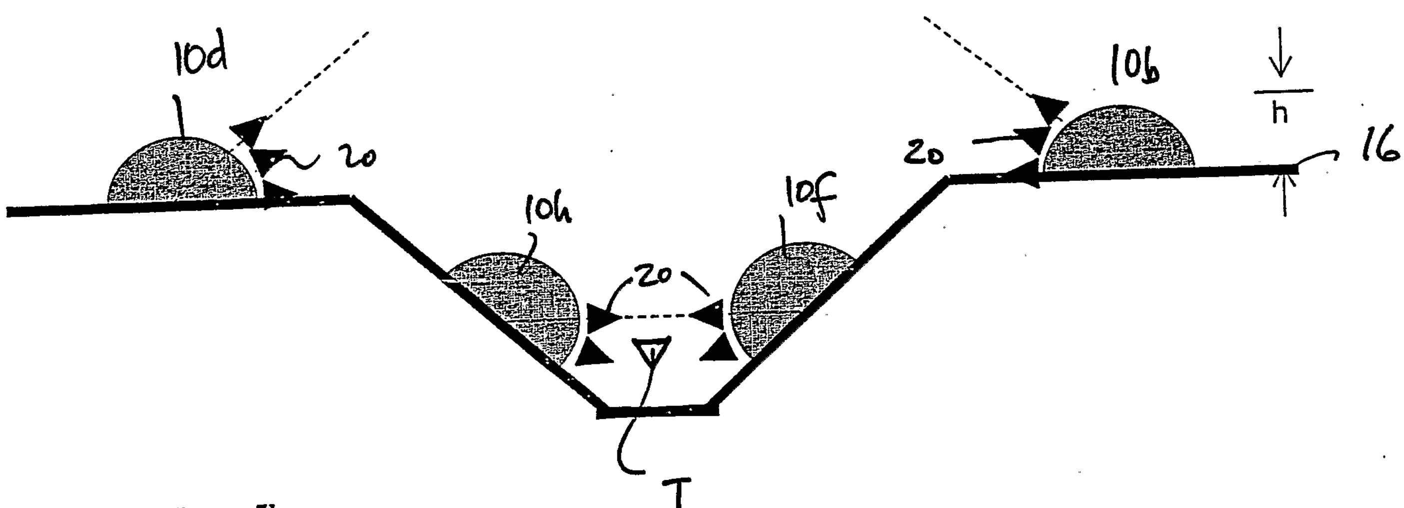

Figure 5b

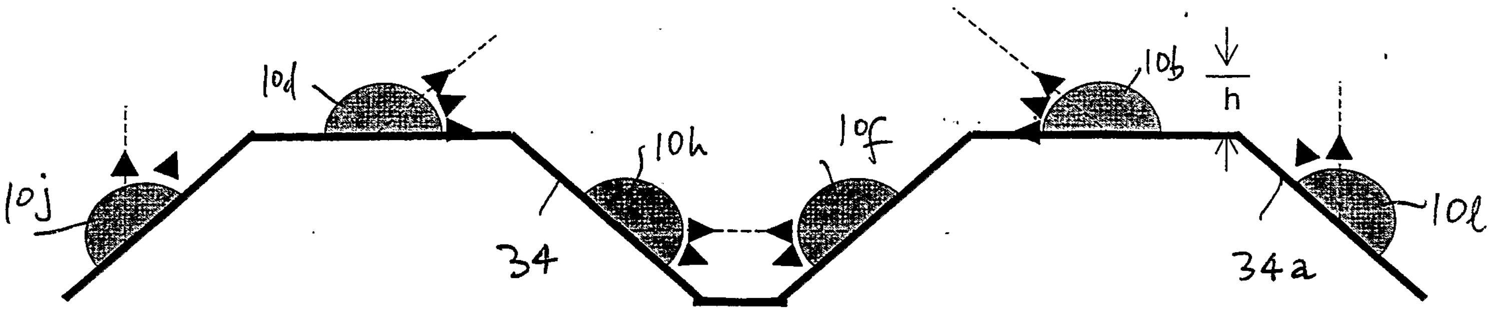

Figure 5c

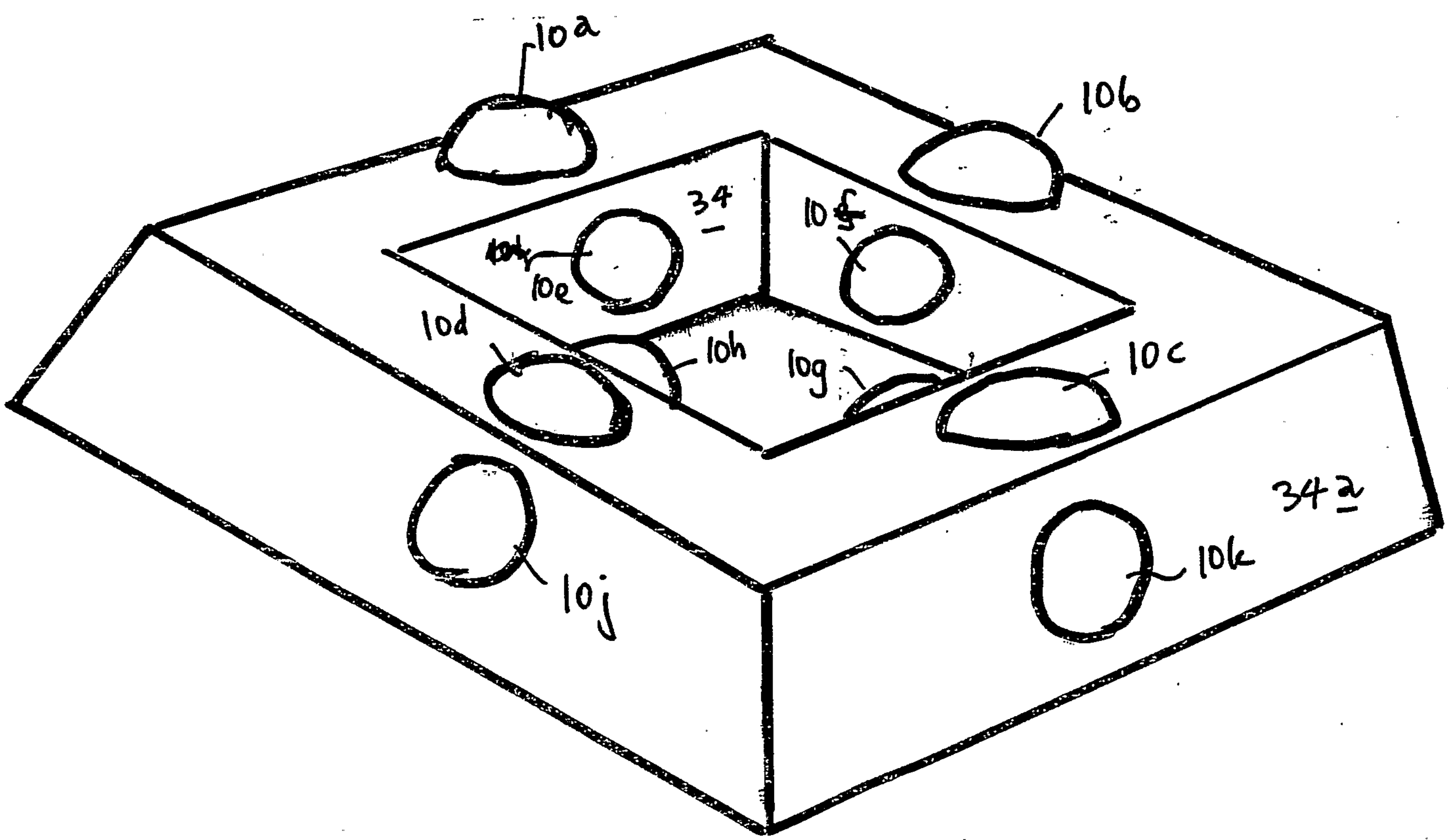

Figure 5d

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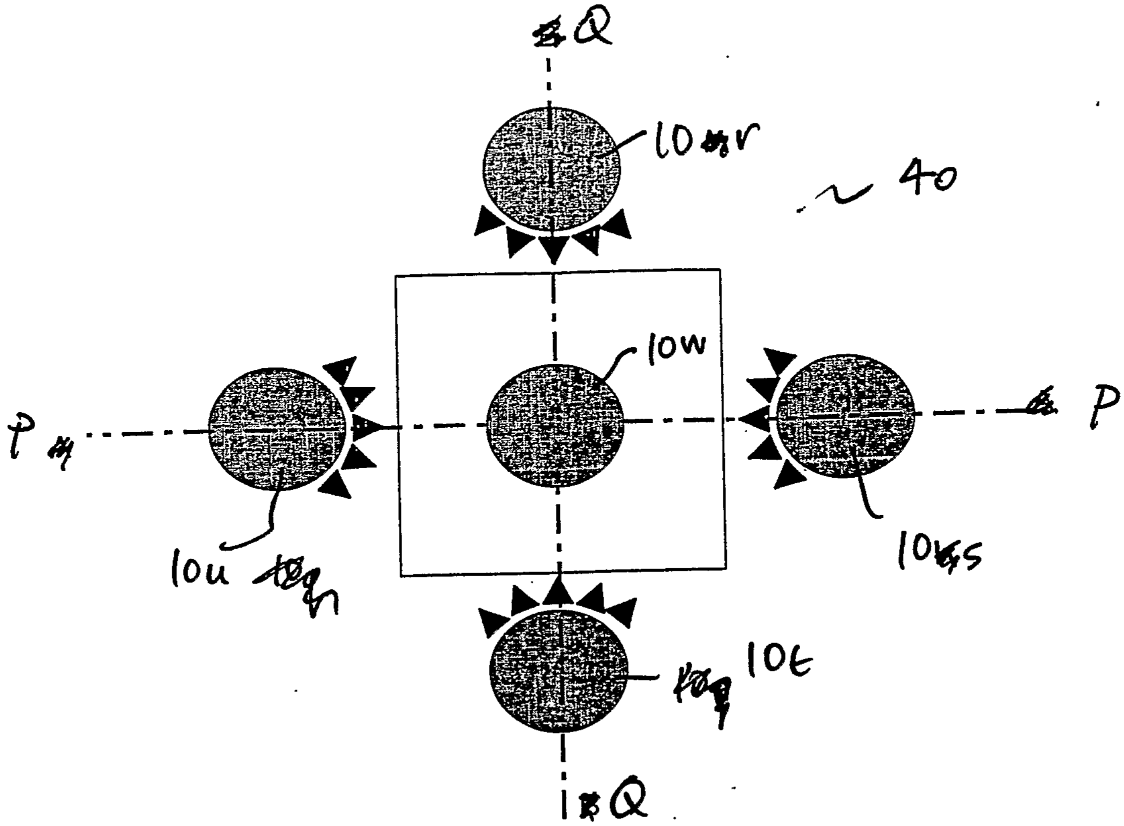

Figure 6a

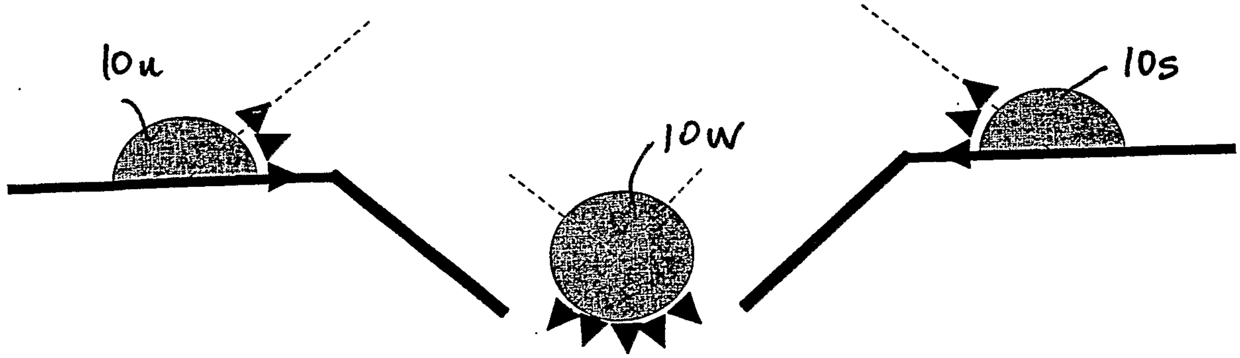

Figure 6b

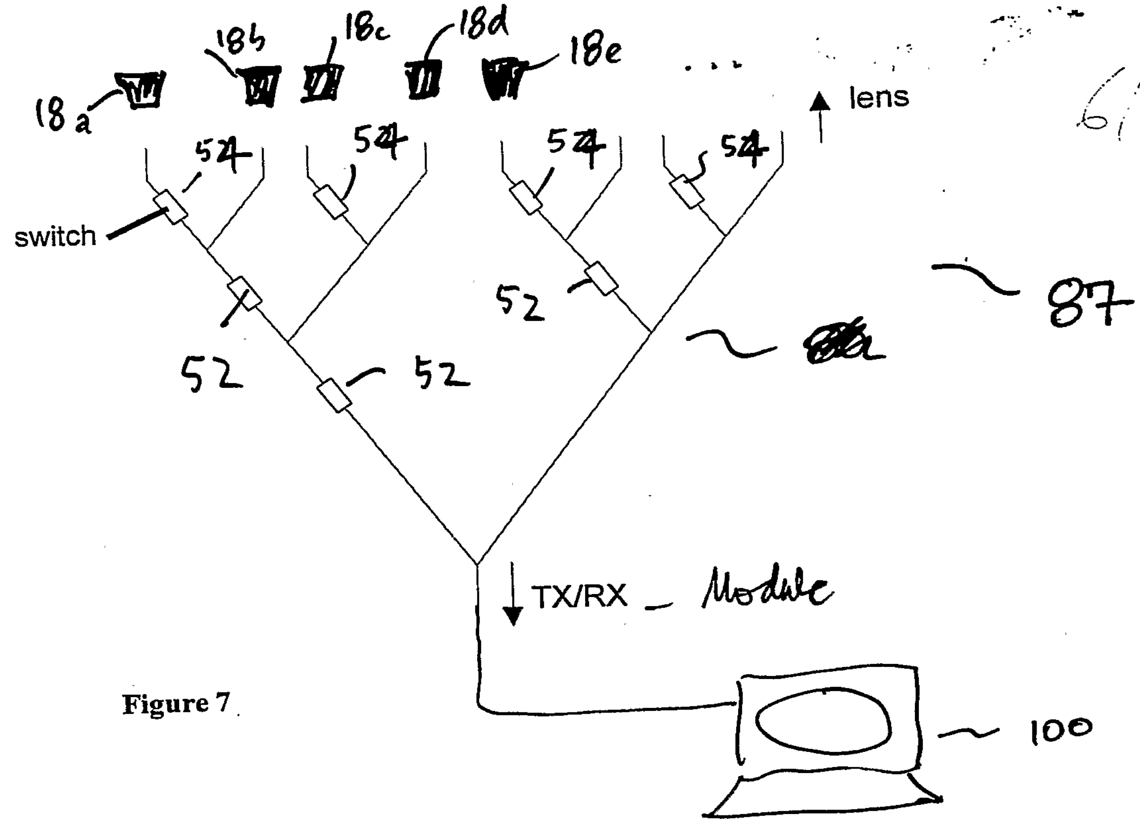

Figure 7

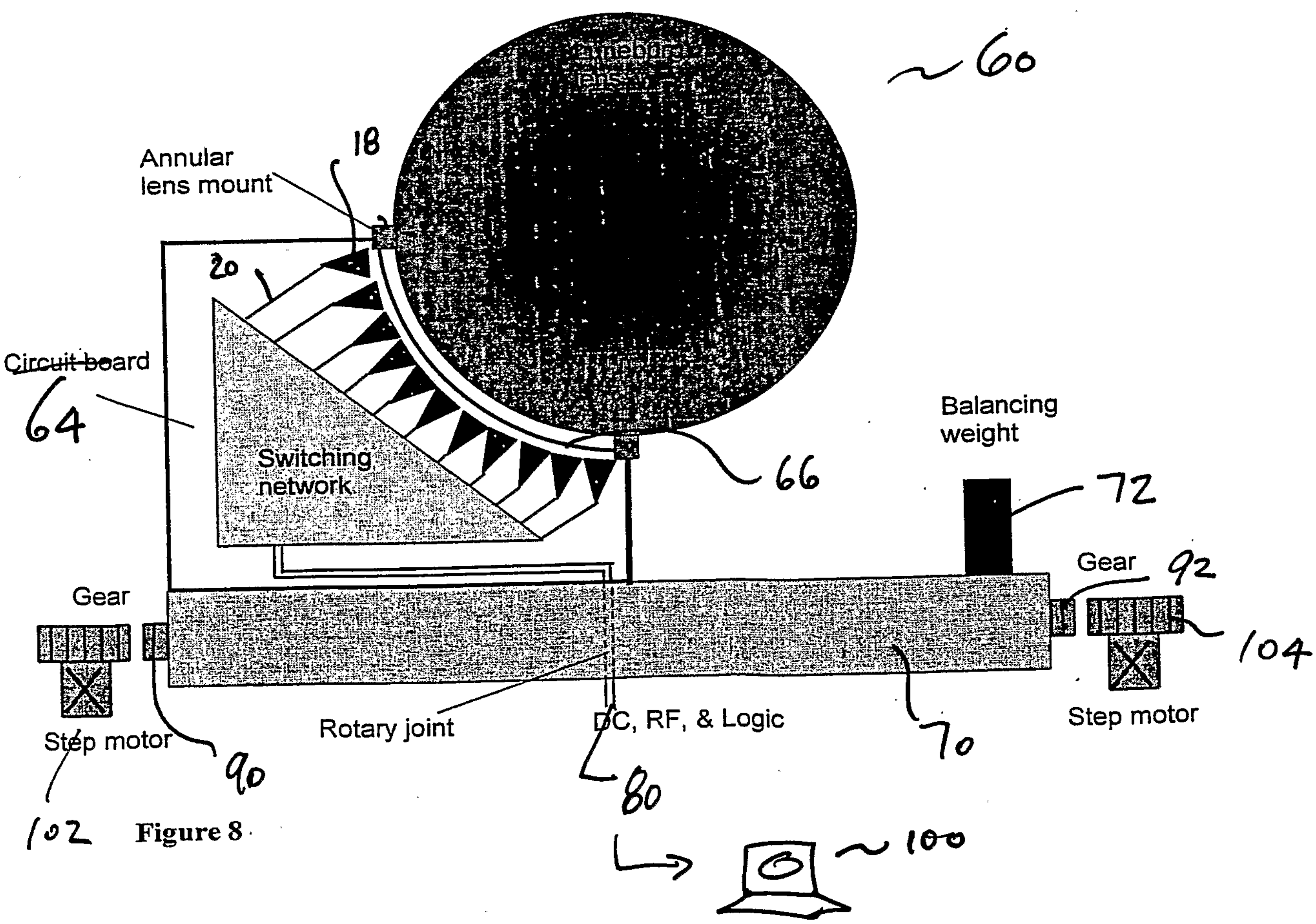

Figure 8

Figure 9:
~~!!!To be added!!!~~